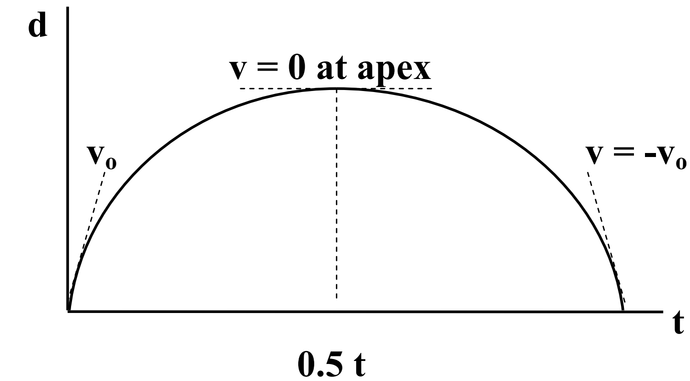
One-Dimensional Projectile Motion

Much of the study of kinematics in Physics 12 involves analysis of objects launched into the air (called **projectile motion**). In these cases, the only acceleration considered is that of gravity, acting vertically downward regardless of the direction of the object's motion.

Consider the simple motion of a baseball tossed straight upwards from ground level and allowed to drop back down to that level where it is caught (similar to Example 1).

a) Examine a distance-time graph of the baseball's motion:

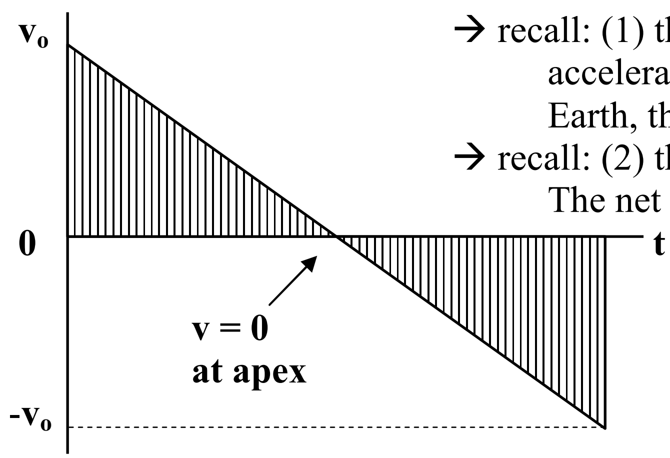
→ recall that slope of a **d-t** graph = velocity (use tangent lines here to represent the slope of a curved line)



b) Now examine a velocity-time graph of the same baseball's motion:

→ recall: (1) that the slope of a **v-t** graph equals acceleration; for any projectile close to Earth, that slope is **g** = -9.8 m/s^2

→ recall: (2) that the area "under" the line equals The net displacement of the baseball



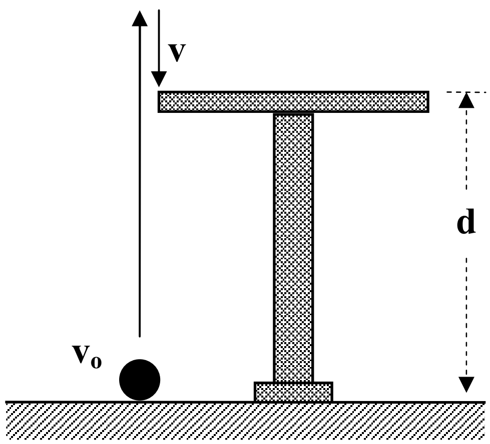
You can see that there are two distinct triangle areas shown.

- The first triangle, above the x-axis, is a *positive* area, representing the upward displacement of the baseball from where it is thrown to its maximum height.
- The second triangle, below the x-axis, is a *negative* area to show the downward displacement from maximum height to where the baseball is caught again.

Note: analysis of graphs is an important aspect of this course. For <u>any</u> given graphing relationship, be sure that you can:

a) make an equation from the line;
b) describe the significance of the slope of the line;
c) state the meaning of the area under the graph.

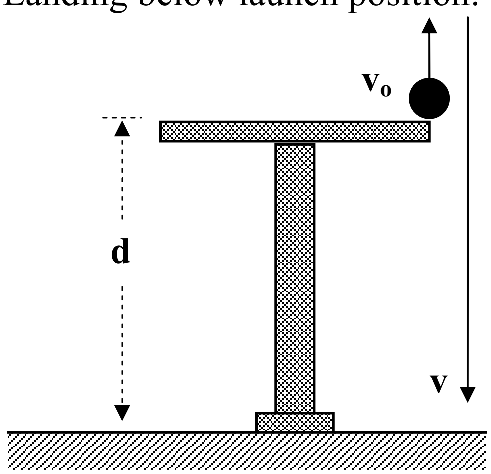
Now consider an object that lands or is caught at a <u>different</u> height from its launch.
(a) Landing above launch position:



→ if "up" is **positive**, then:

a) $\mathbf{v_o}$ is positive
b) $\mathbf{a = -9.8\ m/s^2}$
c) displacement height **d** is positive
d) there are <u>two</u> times, **t**, when height **d** is reached
e) there are <u>two</u> velocities **v** when height **d** is reached (one is +ive, the other -ive)

(b) Landing below launch position:



→ if "up" is **positive**, then:

a) $\mathbf{v_o}$ is positive
b) $\mathbf{a = -9.8\ m/s^2}$
c) displacement **d** is <u>*negative*</u>
d) there is one positive time, **t**, when displacement **d** is reached
e) there is one velocity **v** when displacement **d** is reached; it is <u>*negative*</u>)

The same kinematics formulas can be used to solve problems arising from either (a) or (b) situation. For example:

→ to find time **t** for the projectile to make either trip, use $\mathbf{d = v_o t + \frac{1}{2} a t^2}$

The difference between the problems is only in the sign of the displacement.
A displacement up is positive (diagram 'a'), a displacement down, negative (b).

To solve this type of question, given $\mathbf{v_o}$ and $\mathbf{d}$, substitute into $\quad \mathbf{d = v_o t + \frac{1}{2} a t^2}$
to find $\mathbf{t}$. In this case you'll have to rearrange into the form $\mathbf{at^2 + bt + c = 0}$
and solve using the quadratic formula:

$$\mathbf{t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}}$$ (and you thought this formula had no practical use)

Example 3.
Wile E. Coyote wants to jump onto a cliff 30.0 meters high so, using his Acme spring-loaded tennis shoes, he jumps straight upwards at 25.0 m/s and safely lands on the cliff edge.

a) How long is he in the air?
b) How high did he actually jump?

(see Projectiles Ex 3 for answer)